Department of Energy
Oak Ridge Operations
Weldon Spring Site
Remedial Action Project Office
Route 2, Highway 94 South
St. Charles, Missouri 63303

June 1, 1988

ADDRESSEES

INTERIM RESPONSE ACTION FOR THE ASH POND ISOLATION SYSTEM

Enclosed you will find the revised Engineering Evaluation/ Cost Analysis for the referenced Interim Response Action. This document has been revised to reflect comments received from the EPA and the MDNR (there were no comments from the public) and serves as the responsiveness summary for this response action. It is my understanding that responses to comments have, for the most part, been coordinated with your organization. Therefore, subject to your indication to the contrary we assume that this completes the environmental documentation requirements for this action.

We will complete final design within the next three weeks and will then proceed to award a contract for the work.

If you have any questions, please give me a call.

Sincerely,

J H McEach
for
R. R. Nelson
Project Manager
Weldon Spring Site
Remedial Action Project

Enclosure

cc w/enclosure:
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DOCUMENT NUMBER I-200-203-1.01

ADDRESSEES FOR LETTER DATED JUNE 2, 1988

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PROPOSED INTERIM RESPONSE ACTION: EE/CA

CONSTRUCTION OF ASH POND ISOLATION SYSTEM
AT THE WELDON SPRING SITE

May 1988

DOCUME

DOCUMENT NUMBER: I-200-203-1.02

PROPOSED INTERIM RESPONSE ACTION:

CONSTRUCTION OF ASH POND ISOLATION SYSTEM AT THE WELDON SPRING SITE

SITE BACKGROUND

The Weldon Spring site is located in St. Charles County, Missouri, about 48 km (30 mi) west of St. Louis. From 1941 to 1944, the U.S. Department of the Army operated the Weldon Spring Ordnance Works at the site for production of trinitrotoluene and dinitrotoluene. In the mid 1950s, a portion of the property was transferred to the U.S. Atomic Energy Commission (AEC), a predecessor of the U.S. Department of Energy (DOE).

From 1957 to 1966, the AEC operated a uranium processing facility at the Weldon Spring site. Impure uranium ore concentrates and some scrap uranium metals were processed at the chemical plant, and thorium-containing materials were also processed on an intermittent basis. Following closure by the AEC, the Army reacquired the chemical plant in 1967 and began converting the facilities to produce herbicides. Some of the buildings were partially decontaminated and some equipment was dismantled. In 1969, prior to becoming operational, the herbicide project was canceled. Since that time, the plant has remained essentially unused and in caretaker status. The Army returned a portion of the ordnance works property to the AEC in 1971 but retained control of the chemical plant buildings. In 1984, the Army repaired several of these buildings; decontaminated some of the floors, walls, and ceilings; and removed some contaminated equipment to areas outside of the buildings. In 1985, custody of the chemical plant property was transferred to DOE.

The Ash Pond area is located in the far northwest section of the Weldon Spring site and has the lowest surface elevation on the site (Fig. 1). Water is present only intermittently in Ash Pond and is recharged by surface runoff. The watershed of Ash Pond includes the area around the raffinate pits and and the western quarter (about 25 ha [62 acres]) of the chemical plant area (Fig. 2). Discharge from Ash Pond flows northward to Lake 35, an impoundment on Schote Creek in the August A. Busch Memorial Wildlife Area (U.S. Department of Energy 1987a). Based on the results of dye studies conducted at the site by the Missouri Department of Natural Resources in 1983, a hydraulic connection exists between the Ash Pond outflow stream and Burgermeister Spring, which is also located in the Busch Wildlife Area (Dean 1985). Routine environmental monitoring of intermittent surface runoff has identified substantial levels of uranium contamination in the runoff from Ash Pond.

In order to decrease the release of contaminants off-site, it is proposed that an isolation system (e.g., a dike and diversion channels) be constructed upstream of Ash Pond to limit the flow of surface water over the contaminated area. This report documents the proposed Ash Pond construction project as an interim response action.

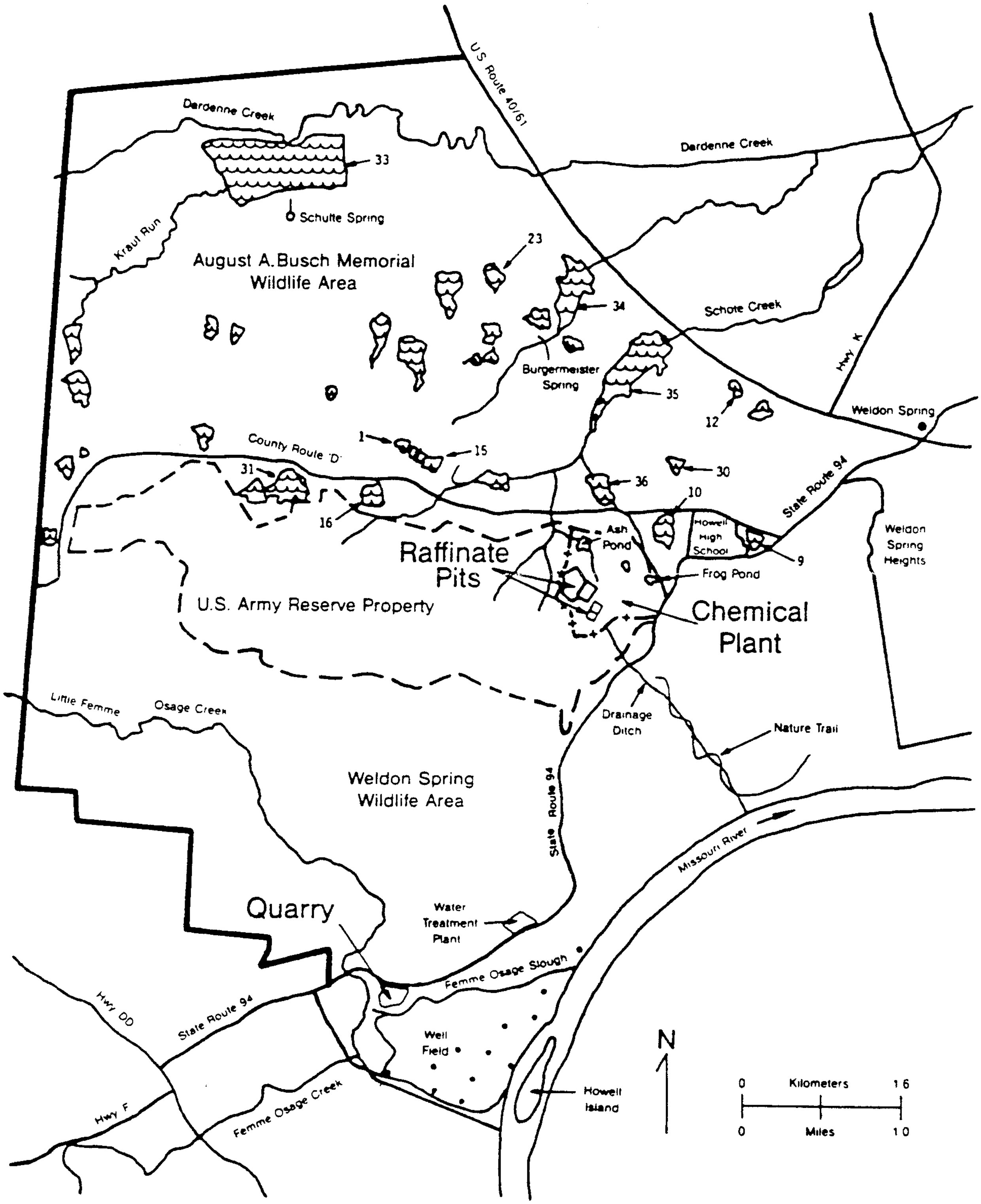

FIGURE 1 Map of the Weldon Spring Site and Vicinity (Source: Modified from U.S. Department of Energy 1987a)

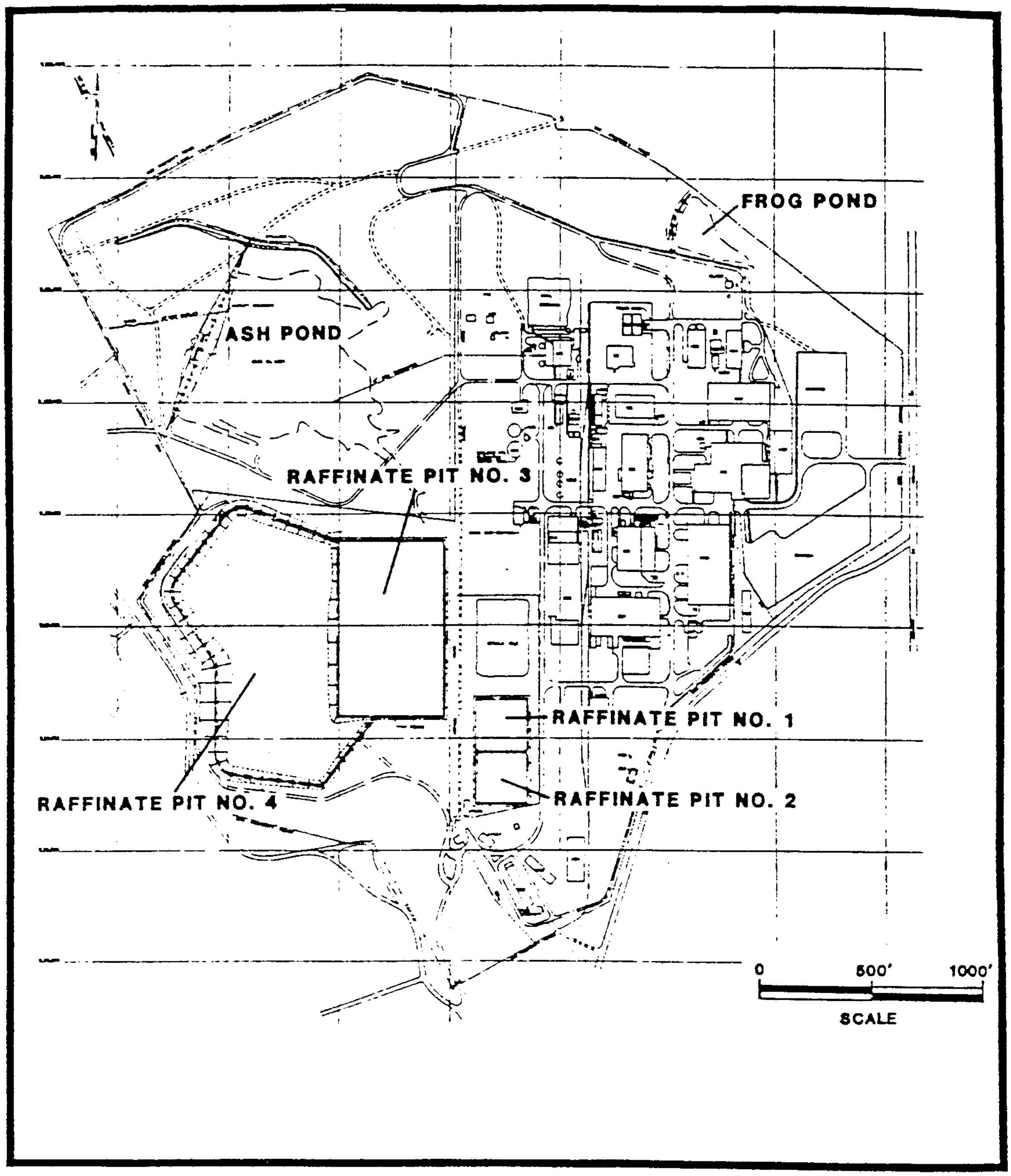

FIGURE 2 Layout of the Weldon Spring Raffinate Pits and Chemical Plant Area

SITE CHARACTERIZATION

Surface Water

A preliminary radiological survey of the Weldon Spring site was performed in 1975. Analyses of water samples from Ash Pond indicated that the concentrations of radium, thorium, and uranium were less than their maximum permissible concentrations (MPCs) as specified in 10 CFR Part 20 (Jacobson 1976; U.S. Department of the Army 1976). (At the time of the survey, 10 CFR Part 20 was the appropriate regulation because the site was under control of the U.S. Department of the Army.) Subsequent radiological sampling identified uranium concentrations in excess of the currently appropriate guideline, i.e., the DOE guideline for uranium-238 in water (600 pCi/L) (U.S. Department of Energy 1986). Levels as high as 4,000 pCi/L were detected in surface runoff from Ash Pond compared with levels up to 400 pCi/L in the watershed upstream from Ash Pond (Kleeschulte and Emmett 1986; MK-Ferguson and Jacobs Engineering 1987).

Recent characterization efforts at the Weldon Spring site have included more extensive sampling for uranium in surface runoff from the Ash Pond watershed. The locations of the sampling points, shown in Fig. 3, were selected because water passing between these points must cross over the known source of radioactive contamination in the watershed -- i.e., the South Dump, which was used for disposal of contaminated material during both the uranium-processing period and the Army's decontamination effort at the site.

Results of the runoff sampling program are presented in Table 1. Because rainfall during the months of April, May, June, August, September, October, and November 1987 was insufficient to produce any flow from the watershed, no water samples were collected during those months. The variable results reflect the nature of the sampling method (i.e., grab samples) and the variable flow volumes. To permit the level of contamination to be more accurately determined, procedures and equipment for continuous monitoring and sequential sampling of surface runoff leaving the area were recently put in place; this effort was completed during May 1988.

Geology and Groundwater

During a recent comprehensive characterization of the Weldon Spring site, several boreholes were drilled in and near Ash Pond (see Fig. 4) to define the physical nature of the area. Analysis of these borehole samples indicated that layers of low-permeability clay are present in the area, with thicknesses ranging from 1.5 to 6 m (5 to 20 ft). The thinnest deposits are present in the existing drainage channel, where compacted fill would be placed during the proposed construction project. A cross section of the Ash Pond area is presented in Fig. 5.

Two piezometers placed in the overburden material immediately south of the proposed dike indicate that the local soil is unsaturated. Groundwater in the area occurs

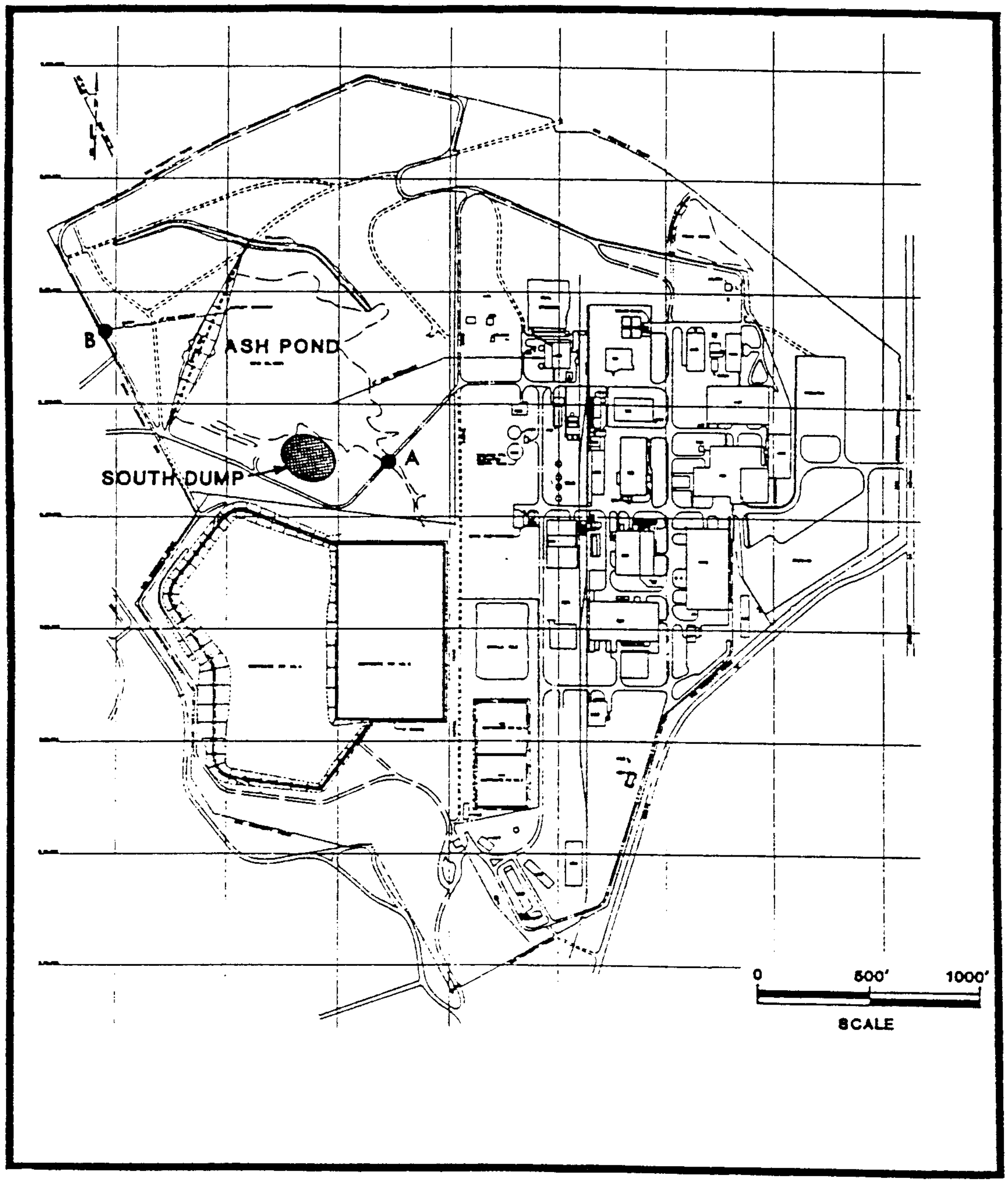

FIGURE 3 Sampling Locations for Uranium in Surface Water at Ash Pond

TABLE 1 Uranium Concentrations in Surface Runoff at the Ash Pond Sampling Points[a]

	Natural Uranium (pCi/L)			
	1987		1988	
Month	Point A	Point B	Point A	Point B
January	-[b]	3,500	140	2,700
			140	2,800
			45	1,800
			110	1,700
			200	360
February	-	3,100	100	460
			180	900
March	380	2,100		
July	100	250		
December	-	960		
	-	1,500		
	-	1,200		
	-	1,800		

[a]The locations of Point A (upstream) and Point B (site boundary) are shown in Fig. 3.

[b]A dash indicates that no data were collected.

in the bedrock, approximately 9 m (30 ft) below the ground surface. Groundwater recharge through this temporary impoundment would be minimal. However, should it occur, the underlying soils would be expected to adsorb contaminants and thus limit migration. (Soils in the area exhibit low hydraulic conductivity and favorable cation exchange properties.) In addition, the proposed upstream isolation dike and diversion channels would significantly reduce the amount of water entering the Ash Pond area, which is believed to be a shallow groundwater recharge area. The resultant decrease in hydraulic head would decrease the rate of infiltration through the contaminated locations in the Ash Pond area (e.g., the South Dump). Based on the thickness and nature of the soils in the affected area, the proposed Ash Pond dike and diversion system would not create a significant groundwater recharge zone. In addition, any water recharging the groundwater from this zone would contain lower levels of uranium than have been

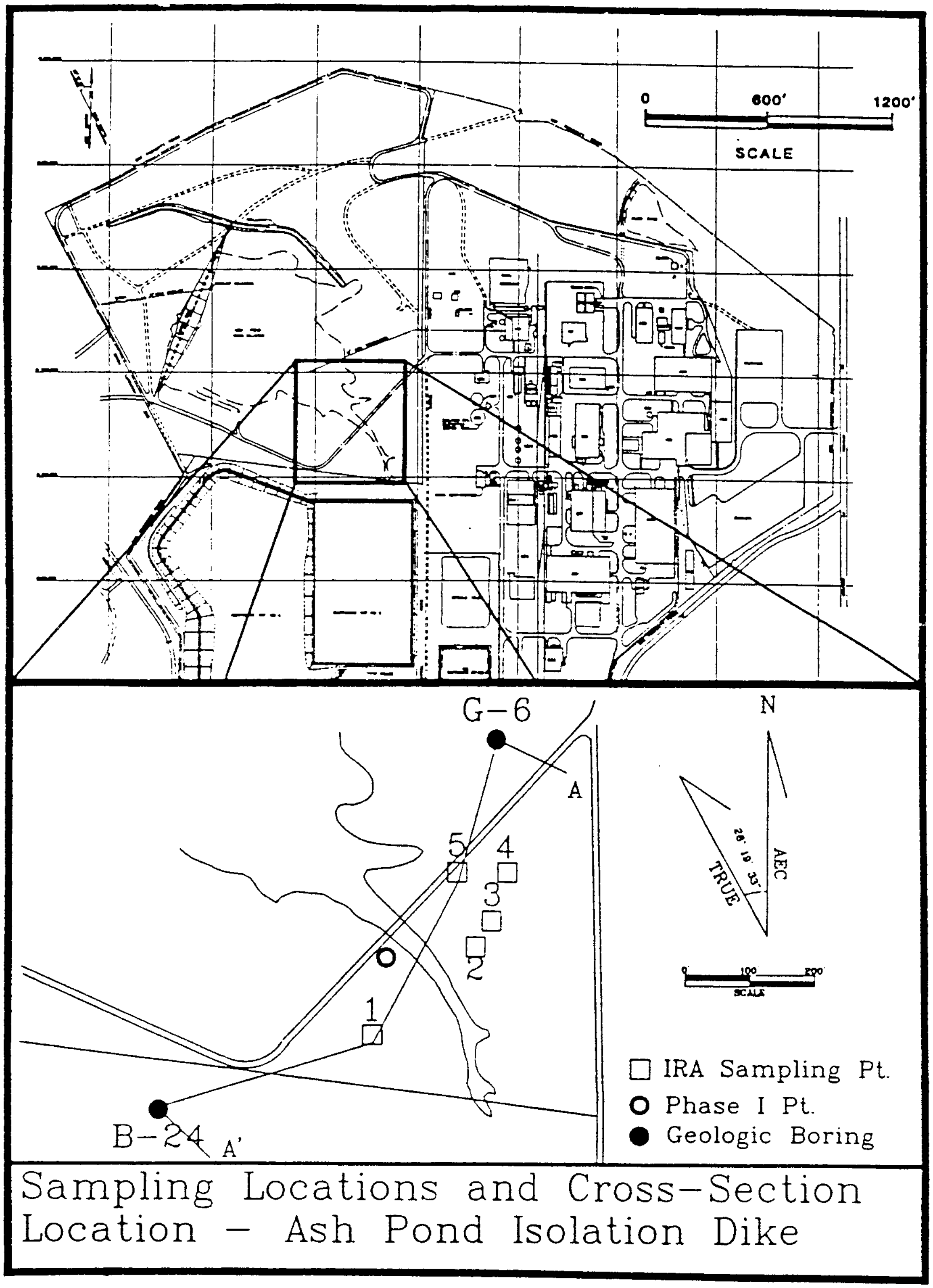

FIGURE 4 Location of Boreholes in the Ash Pond Area

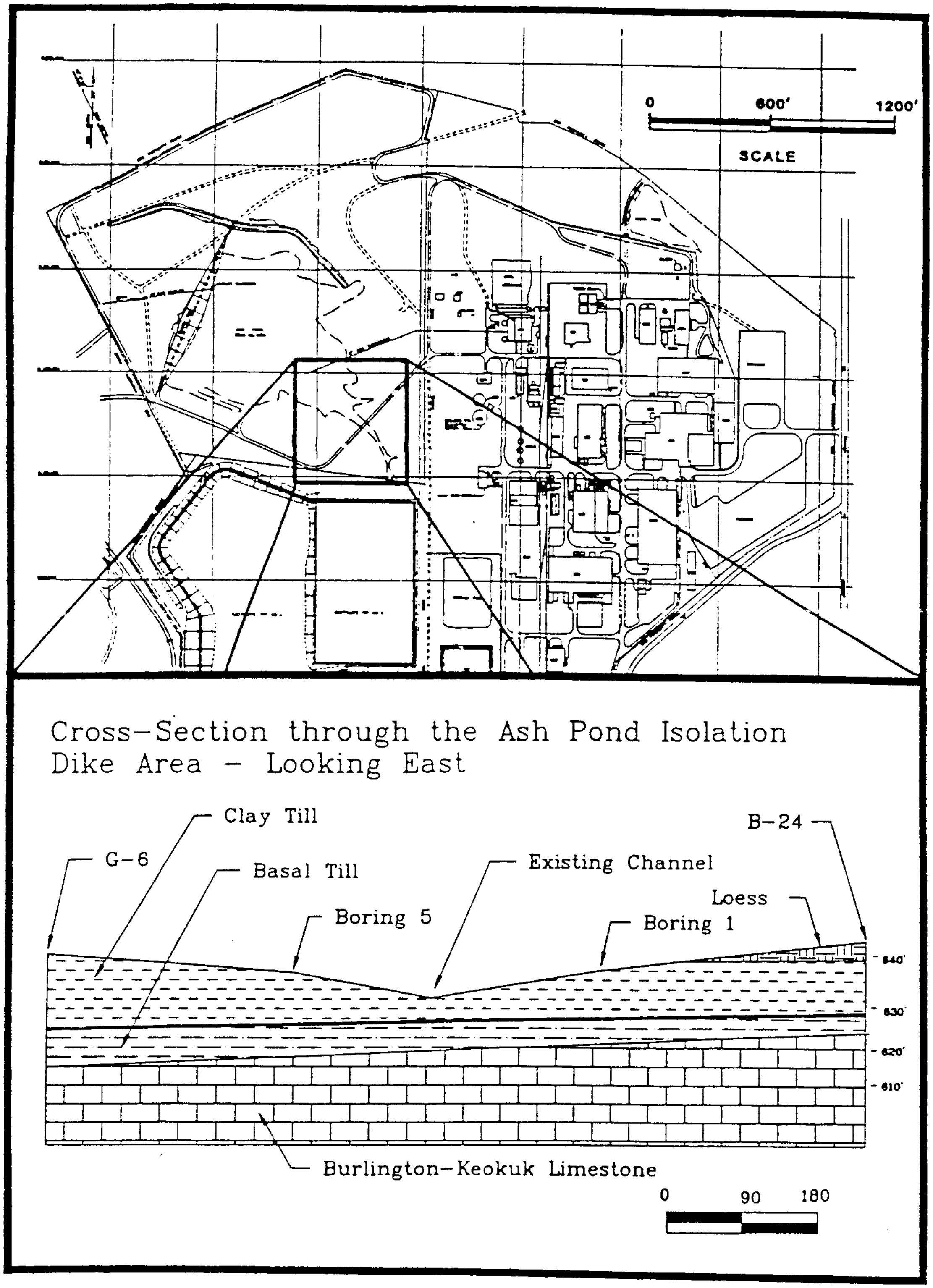

FIGURE 5 Geologic Cross Section of the Ash Pond Area

detected in the losing stream located immediately west of the site. Thus, an improvement in the quality of surface water leaving the Ash Pond area would also improve the quality of the subsurface system (MK-Ferguson and Jacobs Engineering 1988).

Soils

Soils in the Ash Pond area were probably radioactively contaminated as a result of previous processing activities at the Weldon Spring site, migration from the South Dump adjacent to Ash Pond, and past discharges to the pond of decant liquids from the area between raffinate pits 1 and 3 resulting from process line breakage. No known chemical hazards currently exist in the Ash Pond area (MK-Ferguson and Jacobs Engineering 1987).

The Phase I soil investigation program, consisting of a comprehensive radiological and chemical characterization of site soils, was recently completed at the Weldon Spring site (MK-Ferguson and Jacobs Engineering 1988). For the chemical characterization, subsurface soil samples were collected from several boreholes in and around the area proposed for the Ash Pond isolation system (see Fig. 4). These borehole samples Fig. 4) were analyzed for metals, nitroaromatics, inorganic ions (nitrate, sulfate, chloride, and fluoride), and moisture content. Select samples were also analyzed for semivolatile compounds, pesticides, and polychlorinated biphenyls. The results indicated that only nitrate and sulfate levels are slightly elevated, and no chemical hazards exist in the area proposed for the isolation system (MK-Ferguson and Jacobs Engineering 1988).

It is proposed that borrow material for construction of the Ash Pond isolation system be obtained from a spoils pile that is located north of raffinate pit 1 and east of raffinate pit 3 (Fig. 6). This pile probably resulted from the excavation of raffinate pit 4 and typically consists of clayey soils. The spoils pile was chemically characterized during the Phase I soil investigation program. Samples were collected from two locations in the pile and analyzed for metals, nitroaromatics, inorganic ions, and moisture content. No elevated concentrations of chemical contaminants were detected in the samples.

The Ash Pond and spoils pile areas were also surveyed for radiological contamination. The methods employed and values measured during this effort are described in detail in the radiological characterization report for the site (Marutzky et al. 1988). Sampling results for the spoils pile indicate that there is no uranium contamination and that concentrations of radium and thorium are below current DOE guidelines for residual radionuclides in soil (U.S. Department of Energy 1987b), which are provided in Appendix A. (Although DOE has established generic guidelines for radium and thorium in soil, there is no similar guideline for uranium. The guideline for uranium in soil is derived on a site-specific basis.) The pertinent results for the Ash Pond/South Dump area are summarized below.

The analyses of soil samples identified one area south of Ash Pond with a radium-226 concentration above the near-surface (i.e., upper 15 cm [6 in.]) soil guideline,

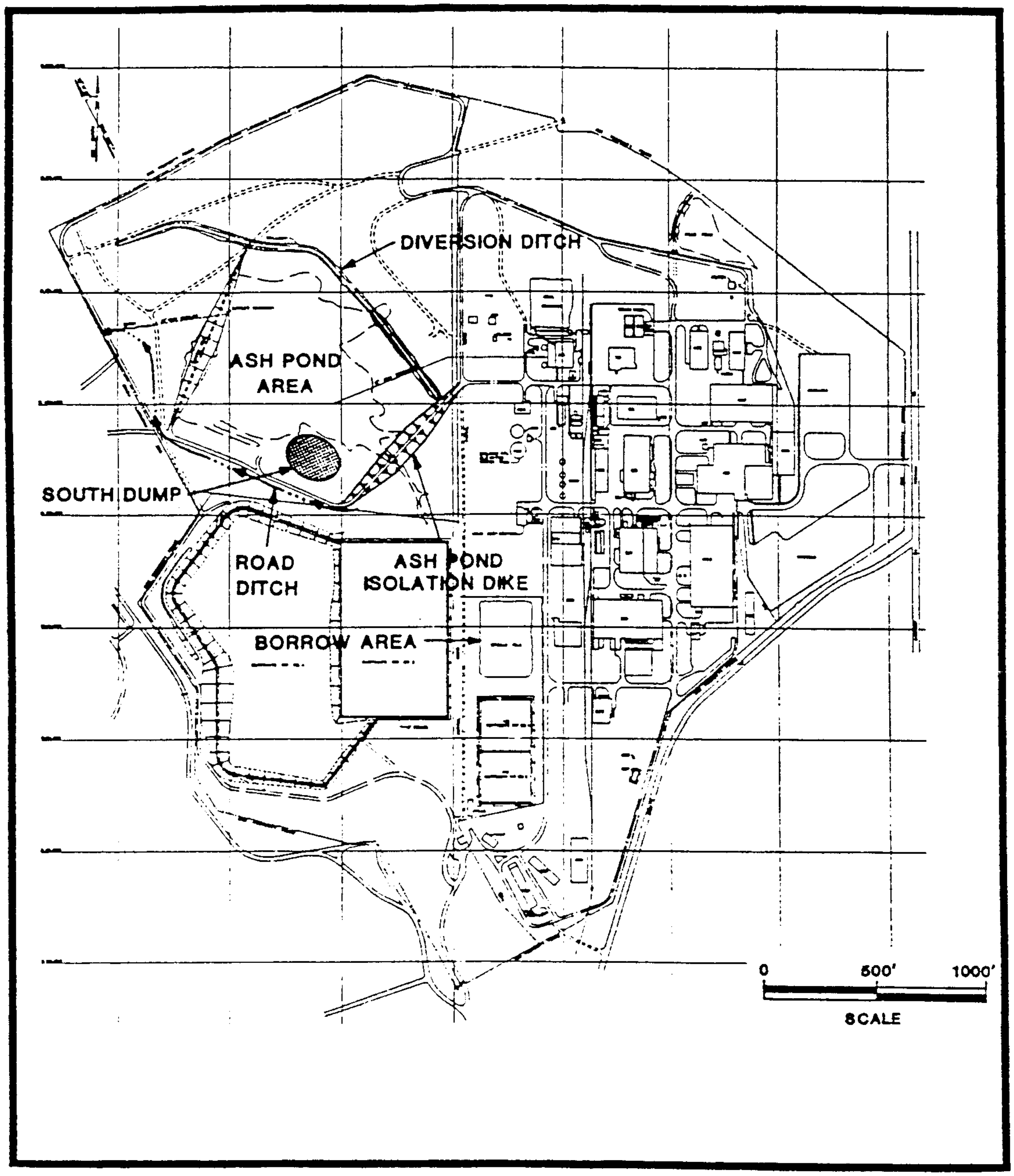

FIGURE 6 Location of Proposed Dike and Borrow Area (Source: Modified from MK-Ferguson and Jacobs Engineering 1987)

but there were no measurements above the guideline for thorium-232 in the area affected by the proposed isolation system. Uranium contamination was detected in the South Dump.

Spectrometric measurements identified two locations southeast of Ash Pond with radium-226 concentrations above the near-surface soil guideline, but no measurements of thorium-232 in the area exceeded the appropriate guideline. Exposure-rate measurements were above background levels in the South Dump.

The subsurface drilling and sampling effort identified the presence of elevated thorium-230 concentrations in the South Dump and elevated uranium concentrations in the Ash Pond/South Dump area. The near-surface soil limit of 5 pCi/g for thorium-230 was exceeded in the South Dump to a maximum depth of 1.2 m (4 ft).

Uranium was detected above 60 pCi/g at maximum depths of 1 m (3 ft) in the South Dump and at greater than 1 m (3 ft) in Ash Pond. Uranium concentrations of 15 pCi/g were detected to a maximum depth of 1.2 m (4 ft) in the South Dump and to a maximum depth of greater than 1 m (3 ft) in Ash Pond. In addition, of 217 boreholes drilled at the site, samples from only two boreholes drilled in the area of the proposed isolation system had radium-226 concentrations above the near-surface soil guideline of 5 pCi/g. A sample from the borehole located east of Ash Pond had elevated radium concentrations to a depth of 0.8 m (2.5 ft), with a maximum of 5.6 pCi/g at a depth of 0.3 m (1 ft). A sample from the borehole located in the South Dump was contaminated to 1 m (3 ft) below the ground surface, with a maximum concentration of 37.5 pCi/g at a depth of 0.3 m (1 ft) (Marutzky et al. 1988).

For comparative purposes, 9 boreholes were drilled off-site to establish background concentrations of radionuclides. The sampling locations (A, B, C, and 1 through 6) are shown in Fig. 7, and the analytical results are summarized in Table 2.

THREAT TO PUBLIC HEALTH AND THE ENVIRONMENT

A potential health and environmental hazard exists at the Weldon Spring site due to high levels of uranium in the outflow from the Ash Pond area. The contamination poses a similar hazard off-site because at least a portion of this outflow, which enters the subsurface just west of the site boundary, surfaces again at Burgermeister Spring in the Busch Wildlife Area. Lake 35 in the wildlife area also receives surface water directly from Ash Pond (MK-Ferguson and Jacobs Engineering 1987). Contamination of Lake 35 and Burgermeister Spring poses a potential health hazard to area personnel, the general public, and resident wildlife.

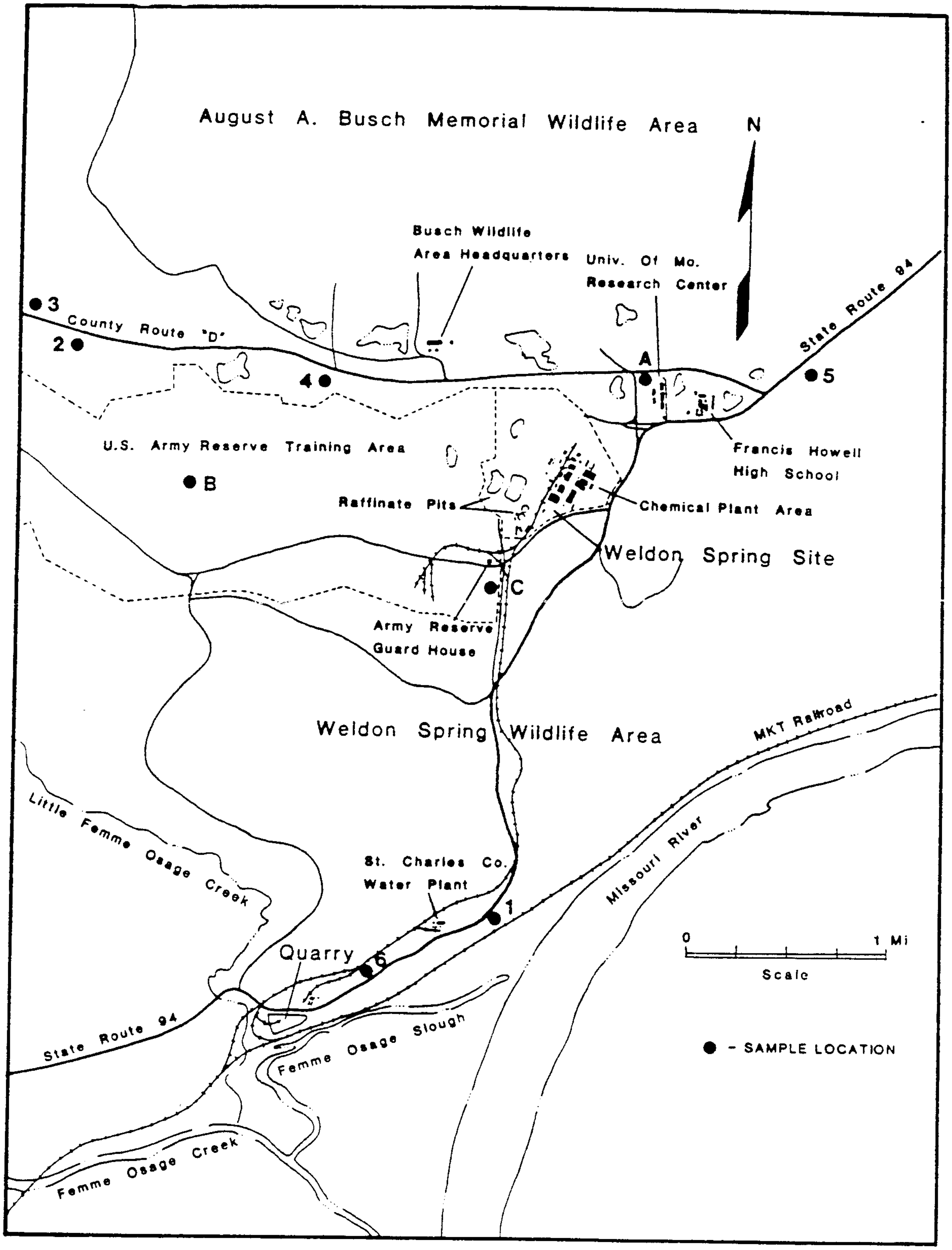

FIGURE 7 Off-site Radiological Sampling Locations (Source: MK-Ferguson and Jacobs Engineering 1987)

TABLE 2 Background Concentrations of Radionuclides in Surface Soil

Off-site Location[a]	Concentration (pCi/g)		
	Radium-226	Thorium-232	Uranium-238
1	0.8	0.9	< DL[b]
2	1.1	0.9	< DL
3	1.3	0.6	< DL
4	0.8	0.8	< DL
5	0.9	1.0	< DL
6	1.1	1.0	< DL
A	0.9	0.7	< DL
B	0.5	1.2	< DL
C	1.2	0.4	< DL

[a]Samples from locations 1-6 were composited over 15 cm (6 in.); samples from locations A-C were composited over 1 m (3 ft).

[b]DL = detection limit (about 1.9 pCi/g).

Source: Data from MK-Ferguson and Jacobs Engineering (1987).

RESPONSE ACTION

Response Action Objectives

The objectives of the proposed response action are as follows:

1. Reduction of the potential on-site health hazard due to uranium contamination of surface water in the Ash Pond area;

2. Reduction of the potential off-site health hazard due to uranium contamination of receiving waters in the Busch Wildlife Area;

3. Reduction of the surface water infiltration rate through contaminated soils in the Ash Pond area; and

4. Improvement in the quality of water being discharged off-site from the Ash Pond area.

These objectives can be met by limiting surface water flow through the contaminated Ash Pond area by means of the proposed isolation system.

Proposed Response Action Alternatives

Interim (expedited) response actions are implemented to ensure the health and safety of on-site personnel and local populations and to minimize or preclude off-site releases of contamination. These actions are limited to those that can be performed under the Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act (SARA), and remain within the constraints of the Council on Environmental Quality's regulations for the National Environmental Policy Act (i.e., actions will be limited to those that do not have an adverse environmental impact nor limit the choice of reasonable alternatives).

The following alternatives have been identified for the proposed interim response action to reduce contamination of surface runoff from the Ash Pond area:

1. No action;

2. Excavation of contaminated material from the Ash Pond area, including the South Dump, which is responsible for radiological contamination of surface flow through the area, with on-site storage of all material that exceeds the radiological criteria for unrestricted release (and on-site interim storage of any material that exceeds limits for chemical contamination, if discovered, pending a disposal decision);

3. Construction of a dike at the site boundary downstream of the Ash Pond area to provide a retention basin for the contaminated water until it can be decontaminated at an on-site water treatment plant; and

4. Construction of an isolation dike upstream of Ash Pond to prevent contact of surface runoff with contaminated material in the Ash Pond area (e.g., the South Dump) and construction of diversion channels to route the water away from these contaminated locations for subsequent outflow at its current off-site discharge point.

Screening and Analysis of Response Action Alternatives

The four alternatives that have been identified for the proposed action are screened and analyzed below on the basis of criteria identified in U.S. Environmental Protection Agency (EPA) guidance for removal actions. These criteria include technical feasibility, environmental impacts, cost, and institutional factors (e.g., timeliness, compliance with ARARs, and protectiveness of public health and welfare).

If no action were taken (Alternative 1), the potential health threat posed by uranium contamination of surface runoff from Ash Pond would not be reduced, nor would on-site or off-site environmental conditions be improved. Although Alternative 1 presents no technical barriers and costs nothing in the short term, it is effectively precluded by the potential for adverse environmental impacts and significant long-term costs (e.g., for the cleanup of areas not currently contaminated but to which contaminants may migrate if no action is taken). It is also precluded by institutional factors related to the community's desire for timely response actions at the Weldon Spring site -- in particular, for a reduction in the off-site release of contaminants.

The action alternatives (Alternatives 2 through 4) are technically feasible and would reduce the potential hazards associated with uranium contamination of surface runoff. Environmental conditions, both on-site and off-site, would be improved if any of these alternatives were implemented.

Alternative 2 is expected to be more expensive than Alternatives 3 and 4. The affected area would need to be protected from surface water intrusion during the excavation period, which would be reflected in costs for constructing an isolation system. In addition to these construction costs, which would be similar to those for Alternatives 3 and 4, Alternative 2 would incur costs associated with storage -- i.e., for all material exceeding radiological release criteria and for chemically contaminated material, if encountered, pending a disposal decision. Thus, a material staging area would be required for Alternative 2; the plan for such a staging area is currently being addressed as a separate interim response action because of a separately identified need. The more extensive planning and documentation that would be required prior to the implementation of Alternative 2, because of its expanded scope as compared to Alternatives 3 and 4, would increase costs and delay the initiation of any mitigative action. Therefore, Alternative 2 would not satisfy institutional factors related to timeliness, i.e., the community's desire for expedited response with regard to minimizing off-site releases of radioactively contaminated water.

The excavation of contaminated material from the area of the proposed interim response action is not unique to Alternative 2; it is being addressed in remedial action plans for the Weldon Spring site and would occur subsequent to the implementation of either Alternative 3 or 4. The excavation would likely be included in the scope of the record of decision for remedial action at the Weldon Spring site. Thus, the selection of either Alternative 3 or Alternative 4 would preclude the need for interim storage of contaminated material because a decision on waste disposal would have been made by the time of excavation. An additional advantage of selecting Alternative 3 or Alternative 4 instead of Alternative 2 is the flexibility to initiate a timely response action at the Ash Pond area, without being tied to a decision that is within the broader scope of overall remedial action for the Weldon Spring site.

Although implementation of Alternative 3 would prevent surface water from leaving the Ash Pond area (i.e., by virtue of a downstream dike), it would do nothing to mitigate the contamination of this water (i.e., the contact of inflow with contaminated materials would continue). Thus, a water treatment plant would be required to treat the contaminated water prior to its release off-site. Costs associated with the construction and operation of a water treatment plant would make Alternative 3 more expensive than Alternative 4. In addition, institutional factors associated with public pressure to minimize off-site contaminant releases would not be completely addressed by Alternative 3. Ponding of water above areas of contaminated soil would increase the local hydraulic head, thereby increasing the potential for infiltration through these areas and the resultant transport of radionuclides into the groundwater. Finally, Alternative 3 would be unsatisfactory in terms of timeliness and other institutional factors related to construction of the water treatment plant. Because approval for this construction has not yet been addressed by the appropriate federal, state, or local agencies, considerable delays could occur prior to construction of the treatment plant.

In contrast to Alternative 3, Alternative 4 would involve diversion of surface runoff away from contaminated areas in the watershed. Not only would this preclude the contamination of surface runoff resulting from contact with these areas and obviate the need for a water treatment plant, it would also effectively reduce the hydraulic head at Ash Pond, thereby decreasing the potential for contaminant transport into the groundwater. Alternative 4 could be implemented in a timely and cost-effective manner and would be protective of the public and the environment by limiting the off-site release of contaminants.

As a result of the screening and analysis process for interim response action alternatives, Alternative 4 has been identified as the preferred alternative. Alternative 4 is consistent with and will contribute to the efficient performance of remedial action being planned for the Weldon Spring site.

Description of the Proposed Response Action

Implementation of the proposed interim response action to construct an upstream dike and diversion channels would result in restricting the flow of surface water across the contaminated areas of the Ash Pond watershed. The response action would include the following operations:

1. Construction of an isolation dike upstream of Ash Pond -- measuring approximately 230 m (750 ft) in length and 3 m (10 ft) at its maximum height, containing about 5,400 m^3 (7,000 yd^3) of uncontaminated soil material, and creating a retention pond covering a maximum of 0.6 ha (1.5 acres) when full;

2. Construction of diversion channels totaling approximately 610 m (2,500 ft) in length and measuring about 1 m (3 ft) in height, which would circumvent the Ash Pond area and connect the dike to the current point of surface water discharge off-site; and

3. Maintenance of the discharge monitoring station currently in place for intermittent measurement of water quality and continuous measurement of the quantity of surface water discharged from the Ash Pond area.

The proposed action would be conducted in accordance with all applicable or relevant and appropriate requirements (ARARs), to ensure protection of the safety and health of on-site workers and local populations and to limit off-site releases of contaminants. Section 121(d)(4) of SARA identifies six conditions under which a waiver from compliance with ARARs may be granted. One of these conditions is that the action is only part of a total remedial action that will attain such levels or standards of control as identified by the specific ARAR when the total remedial action is completed. If it is determined that a waiver application is necessary, e.g., for uranium discharge limits, this condition is applicable to the proposed interim response action because isolation of the Ash Pond area is by definition an interim measure to minimize the off-site migration of contaminants. It is also important to note that, because the proposed action is an interim measure, the effected reduction in the uranium discharge level is not to be interpreted as an accepted discharge limit for the remedial action project at the Weldon Spring site. Instead, this level is specific to the response action and is dictated by the conditions of that intermediate action, the purpose of which is to improve near-term environmental and safety conditions in the Ash Pond area. The DOE will establish project-specific discharge limits and cleanup criteria for the Weldon Spring site in cooperation with the EPA and the Missouri Department of Natural Resources.

Borrow material for construction of the Ash Pond isolation dike and diversion channels would be obtained from a nearby spoils pile located outside the affected area. Results of characterization studies have indicated that this spoils pile poses no chemical hazard and is not radiologically contaminated.

This interim response action would be taken to reduce the concentration of uranium in water leaving the Ash Pond watershed. It is expected that the uranium concentration would be reduced from as high as 4,000 pCi/L to less than 400 pCi/L, which is below the current DOE uranium-238 limit of 600 pCi/L for release to uncontrolled areas (U.S. Department of Energy 1986). The isolated areas responsible for this contamination (i.e., locations in the Ash Pond area, including the South Dump) would be remediated in the future. Implementation of the proposed response action at this time would minimize the potential adverse impacts on health and the environment resulting from continued runoff of highly contaminated surface water from the watershed and would support the long-term response to contaminated conditions in the Ash Pond area.

REFERENCES

Dean, T.J., 1985, *Groundwater Tracing Project, Weldon Spring Area*, Interim Report, Parts 1, 2, and 3, Engineering/Environmental Geology, Geology & Land Survey (April).

Jacobson, J.R., 1976, *Preliminary Radiological Survey of the Weldon Spring Chemical Plant*, Memorandum Report No. 2610, prepared for the U.S.A. Ballistic Research Laboratories, Aberdeen Proving Ground, Md. (April).

Kleeschulte, M.J., and L.F. Emmett, 1986, *Compilation and Preliminary Interpretation of Hydrologic Data for the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles County, Missouri — A Progress Report*, U.S. Geological Survey Water Resources Investigation Report 85-4272.

Marutzky, S.F., R. Colby, and L.S. Cahn, 1988, *Radiologic Characterization of the Weldon Spring, Missouri, Remedial Action Site*, prepared for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri (Feb.).

MK-Ferguson Company and Jacobs Engineering Group, Inc., 1987, *Characterization Report for the Ash Pond Isolation Dike Interim Response Action*, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. (Sept.).

MK-Ferguson Company and Jacobs Engineering Group, Inc., 1988, *Phase I Chemical Soil Investigation Data Report for the Weldon Spring Chemical Plant/Raffinate Pits*, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. (Jan.).

U.S. Department of the Army, 1976, *Assessment of Weldon Spring Chemical Plant in St. Charles County, Missouri*, Office of the Department of the Army Project Manager for Chemical Demilitarization and Installation Restoration, Aberdeen Proving Ground, Md. (March).

U.S. Department of Energy, 1986, *DOE-Derived Concentration Guides for Drinking Water and Breathing Air Contaminated with Radionuclides by Members of the Public*, attachment to memorandum from R.J. Stern (Director, Office of Environmental Guidance) to Distribution (Feb. 28).

U.S. Department of Energy, 1987a, *Draft Environmental Impact Statement, Remedial Action at the Weldon Spring Site*, Office of Remedial Action and Waste Technology, Washington, D.C. (Feb.).

U.S. Department of Energy, 1987b, *U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites* (Revision 2, March).

APPENDIX A

DOE GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

U.S. DEPARTMENT OF ENERGY GUIDELINES
FOR RESIDUAL RADIOACTIVE MATERIAL AT
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM
AND
REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(Revision 2, March 1987)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive material and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactive material, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Department of Energy 1986) and subsequent guidance. More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactive material from basic dose limits, is contained in "A Manual for Implementing Residual Radioactive Material Guidelines" (U.S. Department of Energy 1987), referred to herein as the "supplement".

"Residual radioactive material" is used in these guidelines to describe radioactive material derived from operations or sites over which DOE has authority. Guidelines or guidance to limit the levels of radioactive material and to protect the public and the environment are provided for (1) residual concentrations of radionuclides in soil,** (2) concentrations of airborne

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*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**"Soil" is defined herein as unconsolidated earth material, including rubble and debris that may be present in earth material.

radon decay products, (3) external gamma radiation levels, (4) surface contamination levels, and (5) radionuclide concentrations in air or water resulting from or associated with any of the above.

A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). The basic dose limits are used for deriving guidelines for residual concentrations of radionuclides in soil. Guidelines for residual concentrations of thorium and radium in soil, concentrations of airborne radon decay products, allowable indoor external gamma radiation levels, and residual surface contamination concentrations are based on existing radiological protection standards (U.S. Environmental Protection Agency 1983; U.S. Nuclear Regulatory Commission 1982; and DOE Departmental Orders). Derived guidelines or limits based on the basic dose limits for those quantities are used only when the guidelines provided in the existing standards cited above are shown to be inappropriate.

A "guideline" for residual radioactive material is a level of radioactivity or radioactive material that is acceptable if use of the site is to be unrestricted. Guidelines for residual radioactive material presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement. The basis for the guidelines is generally a presumed worst-case plausible-use scenario for the site.

An "authorized limit" is a level of residual radioactive material or radioactivity that must not be exceeded if the remedial action is to be considered completed and the site is to be released for unrestricted use. The authorized limits for a site will include (1) limits for each radionuclide or group of radionuclides, as appropriate, associated with residual radioactive material in soil or in surface contamination of structures and equipment, (2) limits for each radionuclide or group of radionuclides, as appropriate, in air or water, and, (3) where appropriate, a limit on external gamma radiation resulting from the residual material. Under normal circumstances, expected to occur at most sites, authorized limits for residual radioactive material or radioactivity are set equal to guideline values. Exceptional conditions for which authorized limits might differ from guideline values are specified in Sections D and F of this document. A site may be released for unrestricted use only if site conditions do not exceed the authorized limits or approved supplemental limits, as defined in Section F.1, at the time remedial action is completed. Restrictions and controls on use of the site must be established and enforced if site conditions exceed the approved limits, or if there is potential to exceed the basic dose limit if use of the site is not restricted (Section F.2). The applicable controls and restrictions are specified in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). For sites to be released for unrestricted use, the intent is to reduce residual radioactive material to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual material is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to levels that are as low as reasonably achievable. Procedures for implementing ALARA policy are discussed in the supplement. ALARA policies, procedures, and actions shall be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr. The internal committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), plus the dose from penetrating radiation sources external to the body, shall be used for determining the dose. This dose shall be described as the "effective dose equivalent". Every effort shall be made to ensure that actual doses to the public are as far below the basic dose limit as is reasonably achievable.

Under unusual circumstances, it will be permissible to allow potential doses to exceed 100 mrem/yr where such exposures are based upon scenarios that do not persist for long periods and where the annual lifetime exposure to an individual from the subject residual radioactive material would be expected to be less than 100 mrem/yr. Examples of such situations include conditions that might exist at a site scheduled for remediation in the near future or a possible, but improbable, one-time scenario that might occur following remedial action. These levels should represent doses that are as low as reasonably achievable for the site. Further, no annual exposure should exceed 500 mrem.

C. GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

C.1 Residual Radionuclides in Soil

Residual concentrations of radionuclides in soil shall be specified as above-background concentrations averaged over an area of 100 m^2. Generic guidelines for thorium and radium are specified below. Guidelines for residual concentrations of other radionuclides shall be derived from the basic dose limits by means of an environmental pathway analysis using site-specific data where available. Procedures for these derivations are given in the supplement.

If the average concentration in any surface or below-surface area less than or equal to 25 m^2 exceeds the authorized limit or guideline by a factor of $(100/A)^{1/2}$, where A is the area of the elevated region in square meters, limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the supplement. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

Two types of guidelines are provided, generic and derived. The generic guidelines for residual concentrations of Ra-226, Ra-228, Th-230, and Th-232 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface

- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the appropriate guideline is applied as a limit to the radionuclide with the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit or (2) the sum of the ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity"). Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR Part 192) is: In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions by DOE are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive material is not the cause.

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*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.3 External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μR/h and shall comply with the basic dose limit when an appropriate-use scenario is considered. This requirement shall not necessarily apply to structures scheduled for demolition or to buried foundations. External gamma radiation levels on open lands shall also comply with the basic dose limit, considering an appropriate-use scenario for the area.

C.4 Surface Contamination

The generic surface contamination guidelines provided in Table 1 are applicable to existing structures and equipment. These guidelines are adapted from standards of the U.S. Nuclear Regulatory Commission (NRC 1982)* and will be applied in a manner that provides a level of protection consistent with the Commission's guidance. These limits apply to both interior and exterior surfaces. They are not directly intended for use on structures to be demolished or buried, but should be applied to equipment or building components that are potentially salvageable or recoverable scrap. If a building is demolished, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

C.5 Residual Radionuclides in Air and Water

Residual concentrations of radionuclides in air and water shall be controlled to levels required by DOE Environmental Protection Guidance and Orders, specifically DOE Order 5480.1A and subsequent guidance. Other Federal and/or state standards shall apply when they are determined to be appropriate.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVE MATERIAL

Authorized limits shall be established to (1) ensure that, as a minimum, the basic dose limits specified in Section B will not be exceeded under the worst-case plausible-use scenario consistent with the procedures and guidance provided or (2) be consistent with applicable generic guidelines, where such guidelines are provided. The authorized limits for each site and its vicinity properties shall be set equal to the generic or derived guidelines except where it can be clearly established on the basis of site-specific data -- including health, safety, and socioeconomic considerations -- that the guidelines are not appropriate for use at the specific site. Consideration should also be given to ensure that the limits comply with or provide a level of protection equivalent to other appropriate limits and guidelines (i.e., state or

*These guidelines are functionally equivalent to Section 4 -- Decontamination for Release for Unrestricted Use -- of NRC Regulatory Guide 1.86 (U.S. Atomic Energy Commission 1974), but they are applicable to non-reactor facilities.

TABLE 1 SURFACE CONTAMINATION GUIDELINES

Radionuclides[b]	Allowable Total Residual Surface Contamination (dpm/100 cm^2)[a] Average[c,d]	Maximum[d,e]	Removable[d,f]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 β-γ	15,000 β-γ	1,000 β-γ

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[e] The maximum contamination level applies to an area of not more than 100 cm^2.

[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

other Federal). Documentation supporting such a decision should be similar to that required for supplemental limits and exceptions (Section F), but should be generally more detailed because the documentation covers the entire site.

Remedial action shall not be considered complete unless the residual radioactive material levels comply with the authorized limits. The only exception to this requirement will be for those special situations where the supplemental limits or exceptions are applicable and approved as specified in Section F. However, the use of supplemental limits and exceptions should be considered only if it is clearly demonstrated that it is not reasonable to decontaminate the area to the authorized limit or guideline value. The authorized limits are developed through the project offices in the field and are approved by the headquarters program office.

E. CONTROL OF RESIDUAL RADIOACTIVE MATERIAL AT FUSRAP AND REMOTE SFMP SITES

Residual radioactive material above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A and subsequent guidance or superceding Orders require compliance with applicable Federal and state environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to interim storage, interim management, and long-term management.

a. 5000.3, Unusual Occurrence Reporting System

b. 5440.1C, Implementation of the National Environmental Policy Act

c. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations, as revised by DOE 5480.1 change orders and the 5 August 1985 memorandum from Vaughan to Distribution

d. 5480.2, Hazardous and Radioactive Mixed Waste Management

e. 5480.4, Environmental Protection, Safety, and Health Protection Standards

f. 5482.1A, Environmental, Safety, and Health Appraisal Program

g. 5483.1A, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

h. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive material shall not exceed existing Federal or state standards.

d. Access to a site shall be controlled and misuse of on-site material contaminated by residual radioactive material shall be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The Federal government shall have title to the property or shall have a long-term lease for exclusive use.

E.2 Interim Management

a. A site may be released under interim management when the residual radioactive material exceeds guideline values if the residual radioactive material is in inaccessible locations and would be unreasonably costly to remove, provided that administrative controls are established to ensure that no member of the public shall receive a radiation dose exceeding the basic dose limit.

b. The administrative controls, as approved by DOE, shall include but not be limited to periodic monitoring as appropriate, appropriate shielding, physical barriers to prevent access, and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactive material or cause it to migrate.

c. The owner of the site or appropriate Federal, state, or local authorities shall be responsible for enforcing the administrative controls.

E.3 Long-Term Management

Uranium, Thorium, and Their Decay Products

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the wastes shall not (1) exceed an annual average release rate of 20 $pCi/m^2/s$ and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b. of this section (E.3) to be exceeded and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a. of this section (E.3).

d. Groundwater shall be protected in accordance with appropriate Departmental Orders and Federal and state standards, as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of on-site material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The Federal government shall have title to the property.

Other Radionuclides

f. Long-term management of other radionuclides shall be in accordance with Chapters 2, 3, and 5 of DOE Order 5820.2, as applicable.

F. SUPPLEMENTAL LIMITS AND EXCEPTIONS

If special site-specific circumstances indicate that the guidelines or authorized limits established for a given site are not appropriate for a portion of that site or for a vicinity property, then the field office may request that supplemental limits or an exception be applied. In either case, the field office must justify that the subject guidelines or authorized limits are not appropriate and that the alternative action will provide adequate protection, giving due consideration to health and safety, the environment, and costs. The field office shall obtain approval for specific supplemental limits or exceptions from headquarters as specified in Section D of these guidelines and shall provide to headquarters those materials required for the justification as specified in this section (F) and in the FUSRAP and SFMP protocols and subsequent guidance documents. The field office shall also be responsible for coordination with the state or local government of the limits or exceptions and associated restrictions as appropriate. In the case of exceptions, the field office shall also work with the state and/or local governments to ensure that restrictions or conditions of release are adequate and mechanisms are in place for their enforcement.

F.1 Supplemental Limits

The supplemental limits must achieve the basic dose limits set forth in this guideline document for both current and potential unrestricted uses of a site and/or vicinity property. Supplemental limits may be applied to a vicinity property or a portion of a site if, on the basis of a site-specific analysis, it is determined that (1) certain aspects of the vicinity property or portion of the site were not considered in the development of the established authorized limits and associated guidelines for that vicinity property or site and, (2) as a result of these unique characteristics, the established limits or guidelines either do not provide adequate protection or are unnecessarily restrictive and costly.

F.2 Exceptions

Exceptions to the authorized limits defined for unrestricted use of a site or vicinity property may be applied to a vicinity property or a portion of a site when it is established that the authorized limits cannot be achieved and restrictions on use of the vicinity property or portion of the site are necessary to provide adequate protection of the public and the environment. The field office must clearly demonstrate that the exception is necessary and that the restrictions will provide the necessary degree of protection and will comply with the requirements for control of residual radioactive material as set forth in Section E of these guidelines.

F.3 Justification for Supplemental Limits and Exceptions

Supplemental limits and exceptions must be justified by the field office on a case-by-case basis using site-specific data. Every effort should be made to minimize use of the supplemental limits and exceptions. Examples of specific situations that warrant use of the supplemental standards and exceptions are:

a. Where remedial action would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial action -- even after all reasonable mitigative measures have been taken -- would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where it is clear that the scenarios or assumptions used to establish the authorized limits do not, under plausible current or future conditions, apply to the property or portion of the site identified and where more appropriate scenarios or assumptions indicate that other limits are applicable or necessary for protection of the public and the environment.

d. Where the cost of remedial action for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive material does not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial action will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples include residual radioactive material under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. A site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the level of residual radioactive material must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry model and dose limits	International Commission on Radiological Protection (1977, 1978)
Generic Guidelines for Residual Radioactivity	
Residual concentrations of radium and thorium in soil	40 CFR Part 192
Airborne radon decay products	40 CFR Part 192
External gamma radiation	40 CFR Part 192
Surface contamination	Adapted from U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim storage	DOE Order 5480.1A and subsequent guidance
Long-term management	DOE Order 5480.1A and subsequent guidance; 40 CFR Part 192; DOE Order 5820.2

H. REFERENCES

International Commission on Radiological Protection, 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]

International Commission on Radiological Protection, 1978. Limits for Intakes of Radionuclides by Workers. A Report of Committee 2 of the International Commission on Radiological Protection. Adopted by the Commission in July 1978. ICRP Publication 30. Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index. Pergamon Press, Oxford.

U.S. Atomic Energy Commission, 1974. Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors. June 1974.

U.S. Department of Energy, 1986. Formerly Utilized Sites Remedial Action Program. Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification. Office of Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, Division of Remedial Action Projects. January 1986.

U.S. Department of Energy, 1987. Supplement to U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites. A Manual for Implementing Residual Radioactive Material Guidelines. Prepared by Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory for the U.S. Department of Energy. [In press.]

U.S. Environmental Protection Agency, 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Federal Register 48(3):590-604 (January 5, 1983).

U.S. Nuclear Regulatory Commission, 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, D.C. July 1982.